TRIVALENT ARSENIC REMOVAL WITH THE HELP OF FICUS RELIGIOSA BARK POWDER

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Abstract: In this study a new biosorbent material was prepared from a selected biomass Ficus Religiosa bark for to remove trivalent Arsenic also called (Arsenite) from Arsenite contaminated water to determine its sorbent abilities toward Arsenite and to analyze the effect of different parameter such as pH, adsorbent dose, temperature, time and to perform adsorption study with the help of Langmuir adsorption isotherm and Freundlich adsorption isotherm. Regression analysis was also used to determine regression coefficient .From the overall study and analysis it was analyzed that the material has high efficiency toward removal of Arsenic III from water. Under maximum concentration of bio adsorbent dose 40g/L, pH 7, temperature 25◦C ,time 30 minutes, it was found that biosorbent FRBP would be able to remove 99.91% of arsenic III from laboratory or artificially prepared water samples in distilled water .From the detail study of Langmuir parameters it was found that the value of 'r' bio adsorption efficiency also known as separation factor 'Sf' was 0.9945< 1 indicating favourable biosorption. On comparison between regression coefficient r^2 also called determination factor of Langmuir and Freundlich isotherm it was found that the value of r^2 for initial concentration of 10 mg/L was found to be 0.9945<1 for Langmuir parameter and 0.964<1 for Freundlich parameter that indicates biosorption is more favorable to Langmuir adsorption isotherm and surface coverage value θ of adsorbent was 0.9m^2/g.The biosorption capacity also known as adsorbate binding capacity 'Q' for maxi Arsenite removal was 2.5mg/g at pH 7.8 and metalloid concentration 10mg/L and FRBP concentration 40mg/Value of Q for 10mg/L of Arsenite per 10g/L of FRBP concentration at constant temperature 25C and constant time period of 30 minutes was 1mg/g at pH value7.8.In this study effect of temperature was also studied in which it was found that rate of adsorption decreases as temperature increases which indicates that adsorption was exothermic in nature and adsorption was physical sorption. Comparative study with conventional methods was also performed to determine how much the material is better than other technologies on the basis of percentage of Arsenite removed and it was found that the material is highly efficient than other technology to remove Arsenite.

Index Terms - **Bio Adsorption, Adsorption Isotherm, Arsenite, Biomass, WHO, BIS.**

I. INTRODUCTION

In entire parts of world specifically in south East Asian countries arsenic is found in ground water in high concentration which is consumed by people living in rural area lead to detrimental effect not only in human being but in all life forms causing malady such as cancer in the skin, lung, bladder and kidney other skin changes, (Chaurasia et al, 2014).

Arsenic is listed as WHO 10 chemical of major health related problems .The threshold limit of arsenic in drinking water is 10µg/l as recommended by World Health Organization (WHO) and Bureau of Indian Standards
(BIS, 2012).

An early survey have manifested that the ground water of eastern Uttar Pradesh and Bihar in India contains far higher level of arsenic than is pondered safe for human health.(Srivastava et al, 2016).

The venomousness of arsenic is in the following order:-Arsenic gas>inorganic Arsenic(III)> organic Arsenic(III)> inorganic Arsenic As(V) >organic Arsenic(V)>elemental Arsenic Chaurasia et al.(2014).The adsorption processes using active carbon are revealing to be effective in the removal of heavy metalloids and metals ions but the conventional technologies are expensive and subtle dangerous to workers and monitoring or disposal of their byproduct are not safe environmentally. At this moment there is urgent need of an economical, eco- friendly alternative for arsenic remediation.

Indirect intake of heavy metal by natural material or deceased biomass is known as Biosorption process. Biosorption is an emerging technology which offers best alternative for removal of venomous substances in the form of heavy metal and metalloids, from contaminated water. It involves the use of natural waste material such as byproducts of agriculture , domestic waste products, peel of fruits , vegetables ,microorganisms , casein and lemon ,beat root pulp have high efficiency toward sorption of metal ions. Lenin and tannin present in stem have high sorption capacity and ion exchange capacity. They stop the mobility of metal or metalloid ions. Specially vascular plants species are observed by researchers for their high bio adsorption capacity.

It is founded by researchers that dead biomass has higher metal adsorption capacity and process is nutrient independent. Several factors such as pH, presence of other metal and metalloid ions, the biosorption process is affected by types of biosorbent due to presence of carboxylic acid, phosphates etc. in the cell wall of biomass (Ashraf et al , 2011).

The aim of this study is to remove inorganic arsenic from water with the help of biological waste as bio-adsorbent.

In this study sorption characteristics of **Ficus Religiosa** bark powder will be analyzed for their sorption abilities towards inorganic Arsenic (III) and optimizing the effect of various parameters such as pH ,time, temperature and sorbent concentration by performing batch test and adsorption isotherm study.

1.1 Short Introduction To Ficus Religiosa Plant

Ravindranathan in 2014 his research highlighted Ficus Religiosa plant as large dry season deciduous or semi evergreen tree which grows up to height 30 meters. He also mentioned that it is a species of banyan fig native to south Asia and belongs to the **Moraceae** family and is considered as holy by Hindus and Buddhists. From ancient times, considered as medicinal plant. Different parts of this plant are used to cure various ailments of human body **(**Ravindranathan et al, 2014).This plant have high adsorption capacity and it is also used as bio indicator for monitoring lead, arsenic and other heavy metal micro particles in air.

Figure 1.1: Showing Picture of Ficus Religiosa Plant

II. RESEARCH METHODOLOGY

2.1) Material for Adsorbent:-**Ficus Religiosa Bark** was used as adsorbent raw material. The material was collected from local village area of Lucknow district in Uttar Pradesh, India.

2.1.1) Preparation of Bio- Adsorbent: -To prepare biosorbent Ficus Religiosa Barks were washed with tap water .Then again washed with distilled water and after washing it was dried in sun for 24 hours. After that FRB was grinned into powder of fine mesh having size 75 microns and then it was oven dried at temperature 110 ◦C for 1 hour. After drying it was used for the batch test analysis.

2.2) Material for Adsorbate:-

1) Sodium Arsenite **-** For preparing Arsenite stock solution
2) Diluted HCL - For Maintaining pH

2.3) Preparation Of Stock Solution Trivalent Arsenic:-

1) For batch test for arsenic removal tests, the As (III) Arsenite 10 mg of solid Sodium Arsenite (J.T. Baker, reagent grade) was weighted in micro balance.
2) The powder was put in 1000 ml of distilled water and mixed thoroughly by mechanical shaker.

2.4) Apparatus Required For Batch Test Analysis:-

3) **Distilled Water**- For Preparing Stock Solution of Arsenite
4) **pH Meter** (Elico L1612 India) For Reading pH
5) **Magnetic Stirrer** (Mac)
6) **AAS** (Perkin Elmer PE Analyst Atomic Absorption Spectrophotometer) for determination of the concentration of arsenic (III) in water.
7) **Conical Flask with stopper**
9) **Whitman Filter** (Paper No. 42)
10) **Thermometer** – For measuring temperature

2.5) Batch Test Analysis:

Batch adsorption test was performed by mixing sufficient amount of bio adsorbent material to 1000ml of artificially prepared water samples containing trivalent arsenic in flask with stopper and mechanically shaken for desired time period 30 to 70 minutes .Initial arsenic concentration was 10mg/L in all samples and in all conditions the samples was then studied. The pH of the solution was made constant by adding diluted HCL solution at the end of the desired contact period and the conical flask were filtered with Whitman filter paper no 42. Arsenic III concentration was analyzed before and after bio sorption on Atomic Adsorption Spectrophotometer.

2.6) Bio Adsorption And Adsorption Isotherm Analysis

2.6.1) Capacity (Q):

Capacity of bio adsorbents to adsorb heavy metalloid and metal ions are judged by metal sorption capacity Q.
Formula for determining metal sorption capacity:-

$$Q= V\ (Ci-Cf)/S \qquad [1]$$

V= volume of solution in Litres, Ci =initial concentration of arsenic mg/L, Cf is the final concentration of arsenic mg/L, S= dry weight of bio adsorbent in g.

2.6.2) Adsorption Isotherm Study

Langmuir and Freundlich isotherm model were used for to determine adsorption characteristics:-

2.6.2.1) The adsorption isotherm for Langmuir equation is given by:-

$$1/qe =1/qo.bCe +1/qo$$

Where qo =maxi amount of the adsorbent concentration per unit weight of biosorbent material to form a complete monolayer on the surface.
Ce = equilibrium adsorbate concentration in the solution (mg/L)
qe = the amount metal ion adsorbed per unit mass of adsorbent.(mg/g)
b = binding energy constant
1/Ce versus 1/qe defines Langmuir adsorption isotherm

or

$$1/x/m =1/b +1/a.b.C \qquad [2]$$

2.6.2.2) Adsorption efficiency of the adsorption process, was calculated by the equation:-

$$r = 1/1+bCe \qquad [3]$$

if r=1 excellent adsorption efficiency or favorable adsorption efficiency ,0> r<1= high adsorption efficiency
Langmuir adsorption isotherm is valid for monolayer adsorption only onto a surface with finite number of identical active site.

2.6.2.3) Surface Coverage (Θ):

$$bCi =\theta/1-\theta \qquad [4]$$

b is adsorbent coefficient and Ci is initial concentration of adsorbate..

2.6.2.4) Empirical formula for Freundlich adsorption equation is given by:-

$$\log x/m= \log K +1/n \log C \qquad [5]$$

Where x= mass of adsorbate mg/L
m= mass of adsorbent mg/L
C= equilibrium concentration of adsorbate in solution mg/L
K and n are constant for given adsorbate and adsorbent at particular temperature.
At high pressure 1/n = 0

Or

q= Kf. Cn for microbial parameter [6]

2.6.1.5) Regression analysis was also performed for to know determination factor r^2(Table No.2.6)

SHOWING DRINKING WATER STANDARDS AS PER BIS 10500: 2012

Sr. no.	Substance Or (Desirable Limit)	Unit Of Measurement	Requirement(Desirable Limit)As Per BIS 10500:2012
1	pH	mg/L	6.5-8.5
2	TH	mg/L	300

3	K	mg/L	100
4	CO_3	mg/L	-
5	HCO_3	mg/L	-
6	Ca	mg/L	75
7	Na	mg/L	200
8	Cl	mg/L	250
9	F	mg/L	1
10	Mg	mg/L	30
11	PO_4	mg/L	-
12	NO_3	mg/L	45
13	EC	µs/Cm	-
14	SO_4	mg/L	200
15	As	mg/L	0.01mg/L

III. RESULTS AND DISCUSSION

3.1Result of batch test analysis

The study was carried out at ambient temperature 25 ◦C, time 30 minute, pH 7 and initial concentration of arsenic 10 mg/L.The effect of adsorption dose, contact time, pH and Temperature has been investigated for the adsorption rate of Arsenic III for a time interval of 30 to 70 minutes because, it attains equilibrium at 70 minutes and adsorption isotherm study was also performed to analyze the adsorption efficiency and its type.

Table 3.1.1: Showing Effect Of Adsorbent Dose

Sr. no.	Adsorbent dose	Initial conc. of Arsenic (III)	Final conc. of Arsenic (III)	Arsenic III removed from contaminated water	% of As(III) removed	Time in minutes	Q mg/g	Reading of pH after biosorption	Temp◦C
1	10 g/L	10 mg/L	1.5 mg/L	8.5 mg/L	85%	30 min.	0.85	7	25◦C
2	20 g/L	10 mg/L	0.1 mg/L	9.9 mg/L	99%	30 min.	0.495	7	25◦C
3	30 g/L	10 mg/L	0.05 mg/L	9.95 mg/L	99.50%	30 min.	0.33	7	25◦C
4	40 g/L	10 mg/L	0.009mg/L	9.991mg/L	99.91%	30 min.	0.24	7	25◦C

3.1.1 Effect of adsorbent dose on the removal of Trivalent Arsenic: - In the present study batch test has been performed to investigate the effect of bio -adsorbent dose on the removal of trivalent arsenic. From the above observation table no. 1.1 it has been proven that maximum removal of trivalent arsenic was 99.91% which was achieved at optimum dose of 40g/L of Ficus Religiosa bark powder (FRBP) at pH value 7 and minimum trivalent arsenic adsorption has been occurred at minimum dose of 10 g/l of (FRBP) which has removed 85% of total trivalent arsenic concentration from water sample at pH value 7 and constant temperature of 25◦C.

Here biosorption capacity (Q) of biosorbent (FRBP) was also calculated and shown in the table It was observed that for different biosorbent concentration the biosorbent capacity increased as biosorbent dose increased from 0.8mg/g to 0.244mg/g. At biosorbent capacity 0.244mg/g maximum adsorption takes places as shown in table given above

Table 3.1.2: Effect Of Contact Time

Sr. no.	Adsorbent dose	Time in minutes	Initial conc. of Arsenic(III)	Arsenic(III) removed from contaminated water	% of Arsenic(III) removed	pH	Temp. ◦C
1	10 g/L	30min.	10 mg/L	8.5 mg/L	85%	7.4	25◦C
2	10 g/L	40min.	10 mg/L	9 mg/L	90%	7.6	25◦C

3	10 g/L	50min.	10 mg/L	9.9 mg/L	99%	7.7	25◦C
4	10 g/L	60min.	10 mg/L	9.95 mg/L	99.50%	7.8	25◦C
5	10 g/L	70min.	10 mg/L	9.99 mg/L	99.90%	7.8	25◦C

3.1.2) Effect of contact time on the removal of trivalent arsenic: In the batch test analysis effect of increase in time period for the removal of trivalent arsenic has been studied .In the above observation table it has been shown that there is a rapid increase in the removal rate of trivalent arsenic with the increase in the time period.

Optimum time 70 minutes has been taken as maximum time for removal of 99.90% Maximum level of trivalent Arsenic which has been removed at initial concentration of 10 mg/l of trivalent Arsenic and initial dose of bio adsorbent (FRBP) 10 g/L at temperature 25◦C and pH 7.8 .Therefore it has been found that rate of time period also affects the sorption rate.

After 70 minutes no further more bio adsorption was observed in the batch test of Arsenic (III) .Therefore at optimum time 70 minutes equilibrium was established.

Table 3.1.3: Effect of Temperature

Sr. no	Temperature	Initial conc. of Arsenic (III)	% of As (III) removed	Time in minutes	pH
1	25◦C	10 mg/L	85%	30min.	7.6
2	30◦C	10 mg/L	82%	30min.	6.9
3	35◦C	10 mg/L	80.02%	30min.	6.8
4	40◦C	10 mg/L	78%	30min.	5.56
5	45◦C	10 mg/L	75%	30min.	5.2

3.1.3) Effect of temperature on the removal of trivalent Arsenic: In the batch test analysis it has been found that temperature also plays an important role in the removal of trivalent Arsenic. It was performed at initial concentration of trivalent Arsenic 10 mg/L, initial dose of bio adsorbent (FRBP) 10 g/L, pH 7, temp 25◦C and time 30 minute.

In this study it has been observed that maximum bio adsorption 85% occurred at minimum temperature of 25◦C and minimum bio adsorption 75% occurred at maximum temperature 45◦C.Therefore 25◦C is taken as optimum temperature for the removal of trivalent Arsenic. .In this study effect of temperature was also studied in which it was found that rate of adsorption decreases as temperature increases which indicates that adsorption was exothermic in nature.

Table 3.1.4 Effect of pH

Sr no.	pH	Arsenic III Concentration
1	7.4	85%
2	7.6	99%
3	7.7	99.50%
4	7.8	99.91%

3.1.4) Effect of pH on the removal of trivalent Arsenic- Effect of change in pH value of water sample has been investigated for the change

in removal of trivalent arsenic in water sample and it has been shown in observation table no 1.4 given above, it was found that maximum bio- adsorption of trivalent arsenic has been achieved at pH 7.8 which was 99.91% and minimum at pH 7.4 which was equal to 85%. The removal of trivalent Arsenic III was performed at ambient temperature 25◦C and contact time 8 hours for initial arsenic III concentration of 10mg/L at different pH . The pH of solution after adsorption was measured and was found that maximum adsorption was taken place at pH value 7.8 and above this pH the adsorption rate of trivalent arsenic becomes constant.

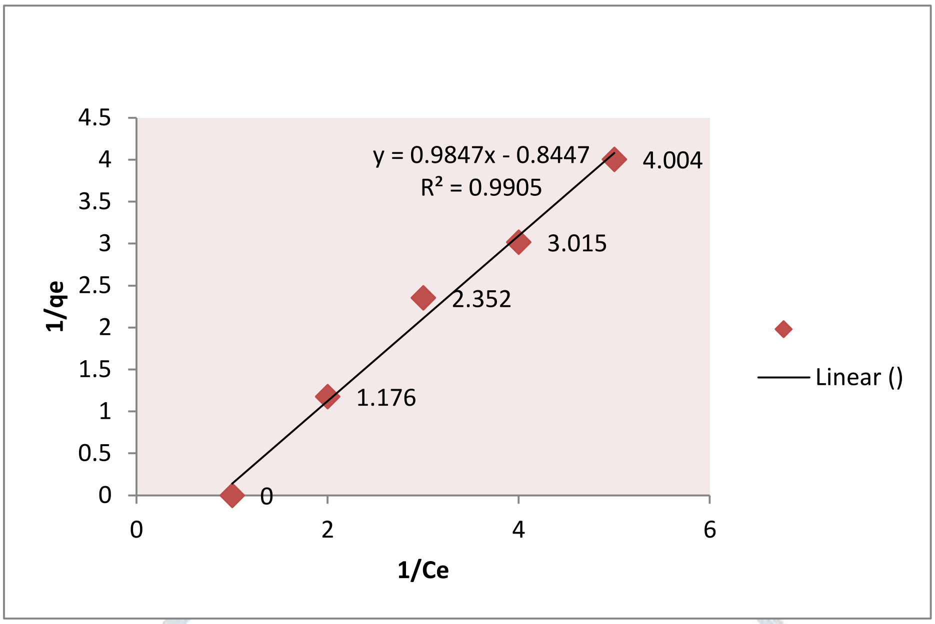

Figure 3.1.5: Graph Showing Langmuir Adsorption Isotherm plotted b/w 1/qe and 1/Ce

Table.3.1.5 Result Of Langmuir And Freundlich Isotherm Analysis

Sr. no.	Langmuir Parameter	Freundlich Parameter
1	q = 70.9219	Kf = 19.624
2	b = 0.401	1/n = 0.4505
3	r^2= 0.9905	r^2 = 0.961
4	r = 0.9945	-

3.1.5) Result of Langmuir and Freundlich isotherm analysis: From the study of isotherm it was observed that Langmuir isotherm is more favourable than Freundlich isotherm .Adsorption efficiency of Langmuir isotherm shown in the table above and the value of regression coefficient r^2 is 0> 0.9905 < 1 which is showing higher adsorption efficiency of biosorbent Ficus Religiosa bark powder than adsorption efficiency of Freundlich isotherm is r^2 0>0.961<1 showing high adsorption efficiency and is showing favorable sorption ability. The change in the removal rate of Arsenic III was due to decrease in adsorption site as well as arsenic III concentration. At initial stage all sites are vacant and the adsorbent gradient was high. After that, the arsenic (III) adsorption rate decreased at saturation point due to decrease in number of vacant sites.

Separation factor r showing adsorption efficiency for Langmuir isotherm 0.9946 <1 is also showing favourable monolayer adsorption process.
At initial stage all sites are vacant and the adsorbent gradient was high. After, the arsenic III adsorption rate decreased at saturation point due to decrease in number of vacant sites

and surface coverage value θ of adsorbent was 0.9m^2/g for Langmuir adsorption isotherm .

Table 3.1.6: Comparison with Previously Used Conventional Technologies:

Technology	Chemical reagent	As(III) removal efficiency	As(V) removal efficiency	Ideal Conditions pH	References
Coagulation filtration	Ferric chloride Ferric Sulphate	<30 <30	<90 80-90	6-8	**Duarte (2009)**
Adsorption	Activated carbon or activated alumina iron hydroxide	30-60 30-60	>95 >95	6-6.5 Ph near 8	**Duarte (2009)**

Ion exchange	Anion exchange resin	<30	>95	5.5-6	**Duarte (2009)**
Membrane Filtration Nanofilteration Reverse osmosis	No chemical reagent	60-90 80-95	>95	Presence of dissolved arsenic As	**Duarte (2009)**
Bio adsorption On Ficus Religiosa bark powder	No chemical reagent	99.91	-	7-8	**Self-analyzed Data**

1) On comparison with other conventional technologies which was tabulated above it has been proven that this material is more effective in removing arsenic (III) than other technologies and have low cost also and it does not contain any chemical reagent. On comparison with coagulation method it has been shown in the table that this material has 69.91% more efficiency to remove arsenic than Ferric Chloride and it can also remove arsenic III at high pH value.

3)On comparison with activated carbons (Iron hydroxide) which was a chemical also it has been shown that active carb which are commercially available have 39.91 % lower efficiency to remove Arsenic III than Ficus Religiosa bark powder.

4)On comparison with ion exchange method It is found that ion exchange method have 69.91% less efficiency than the bio adsorbent material Ficus Religiosa Bark powder and ion exchange method work on lower pH in comparison with Ficus Religiosa Bark Powder.

5)On comparison with membrane filtration technique it is proven that bio adsorbent has 4.91 % higher efficiency to remove arsenic (III) than membrane filtration technique.

IV. CONCLUSION

From the above batch test analysis of the bio - adsorbent the following conclusion were drawn:

1) The material has high efficiency toward removal of Arsenic III from water. Under optimum condition of bio adsorbent dose 40g/L , pH 7- 7.8, temperature 25◦C ,time 70 minutes,
2) The value of r^2 for initial concentration of 10 mg/L was found to be 0.9905<1 and 0.96<1for Langmuir isotherm and Freundlich isotherm that indicates biosorption is more favourable to Langmuir adsorption isotherm process; from the Thermodynamic parameter and it is proven that the process is exothermic in nature because increase in temperature decreases adsorption rate.and adsorption is physical adsorption.
3) From comparative study with the conventional methods previously used it is proven that biosorbent made from Ficus Religiosa Bark Powder has higher efficiency for removing arsenic (III) ions present in water in comparison with conventional technologies and is within prescribed BIS and WHO permissible limit.

From the above observations it proves that the material is suitable for the removal of arsenite from water which requires, further more study.

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